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The Heron Group Report Series
Annotated Briefing

NetWeaver: A New Tool for Developing Results Frameworks, Integrating Performance Data, and Testing Development Hypotheses

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"Facilitating Excellence"

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"Facilitating Excellence"

A NEW TOOL FOR DEVELOPING RESULTS FRAMEWORKS, INTEGRATING PERFORMANCE DATA, TESTING DEVELOPMENT HYPOTHESES, AND MUCH, MUCH MORE!

NetWeaver

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This annotated briefing of a slide presentation about NetWeaver was developed by Dr. Max W. McFadden and Dr. J. Kathy Parker of The Heron Group, LLC and Dr. Michael C. Saunders of The Pennsylvania State University under a Cooperative Agreement with the U.S. Agency for International Development, Bureau for Africa, Office of Sustainable Development, Productive Sector Growth and Environment Division (USAID/AFR/SD/PSGE).

The challenges to USAID to achieve sustainable development are daunting. Sustainable development is an extremely complex issue. It has multiple and diverse components that contribute both directly and indirectly to the diversity and complexity of the issue. For example, consider just one element of sustainable development, the environment. Direct and indirect interdependencies with agriculture, water quality and quantity, human health, forestry, and public policy to name just a few exist. In addition, environment also involves numerous interdependent states and processes such as erosion, siltation, loss of habitat, desertification, etc. The challenges to USAID to understand these complex interactions, manage these challenges and at the same time, strive for sustainable development is a monumental task, indeed.

CHALLENGES TOACHIEVING SUSTAINABLE DEVELOPMENT, cont.

• complexity can be addressed as long as components of the system and their logical relations:

- ❑ are understood in some general way,
- ❑Can be expressed by a Subject Matter Expert

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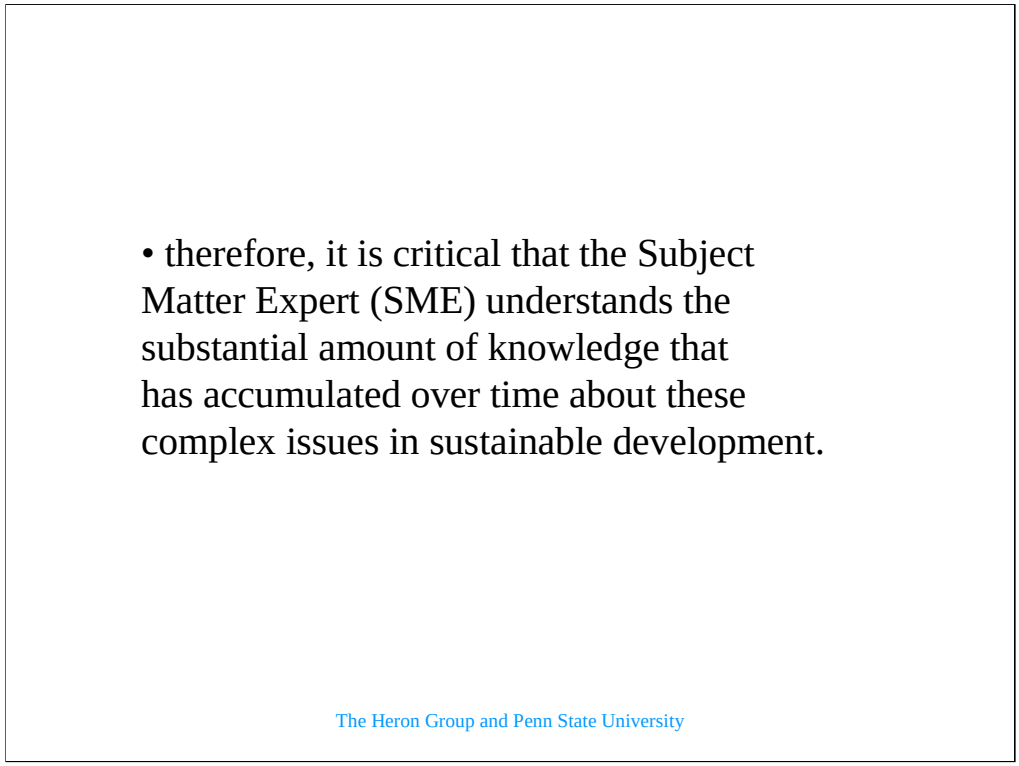
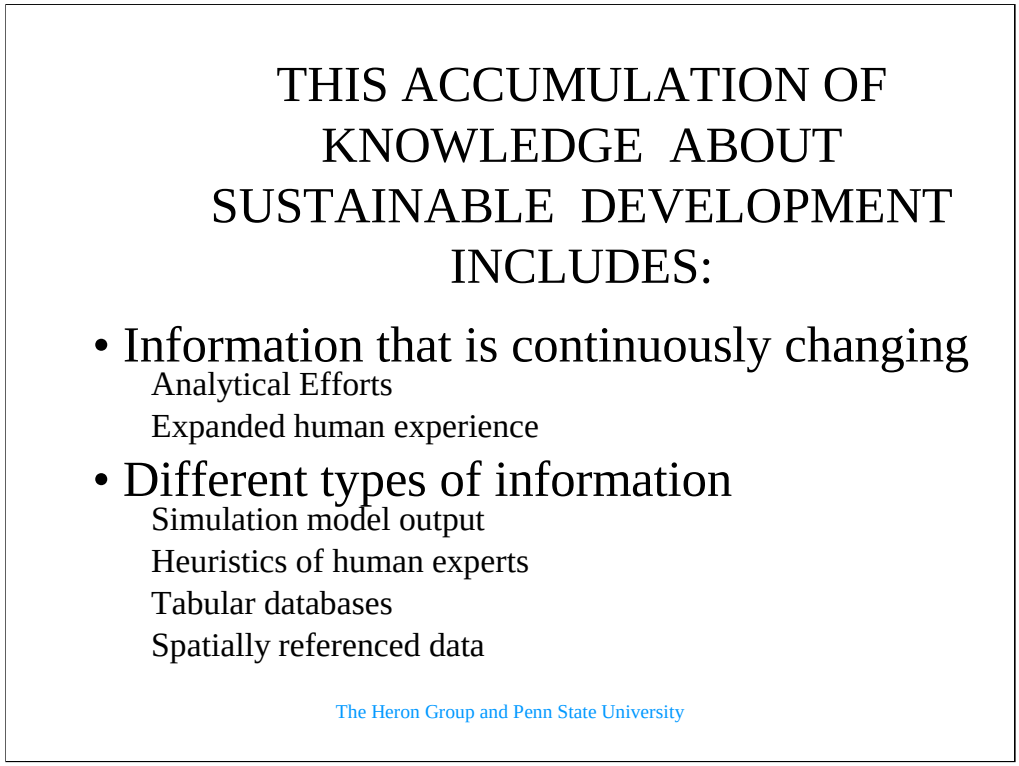
Part of the challenge of sustainable development can be and is handled as data, information, and knowledge. All add to an understanding of the nature and magnitude of complexity of the systems and about the connections between components of the systems and their dynamics.

As understanding increases, it is possible for Subject Matter Experts (SMEs) or Domain Experts to articulate the logical relationships and linkages between the individual parts and the whole. This too is a major challenge, but new tools increasingly are available to condense, process filter, organize, categorize, and analyze disparate pieces of information and then present it as a new synthesis.



Thus, the role of the SME is one of synthesizing and integrating new and emerging knowledge and making it available to others to enhance general understanding about the complex contexts in which sustainable development efforts will be undertaken.



The accumulation of knowledge about sustainable development depends on:

A. Continuously changing information including but not limited to:

1. Analytical efforts including research, special studies, and

2. Expanded human experience from implementation of activities, evaluations, etc.

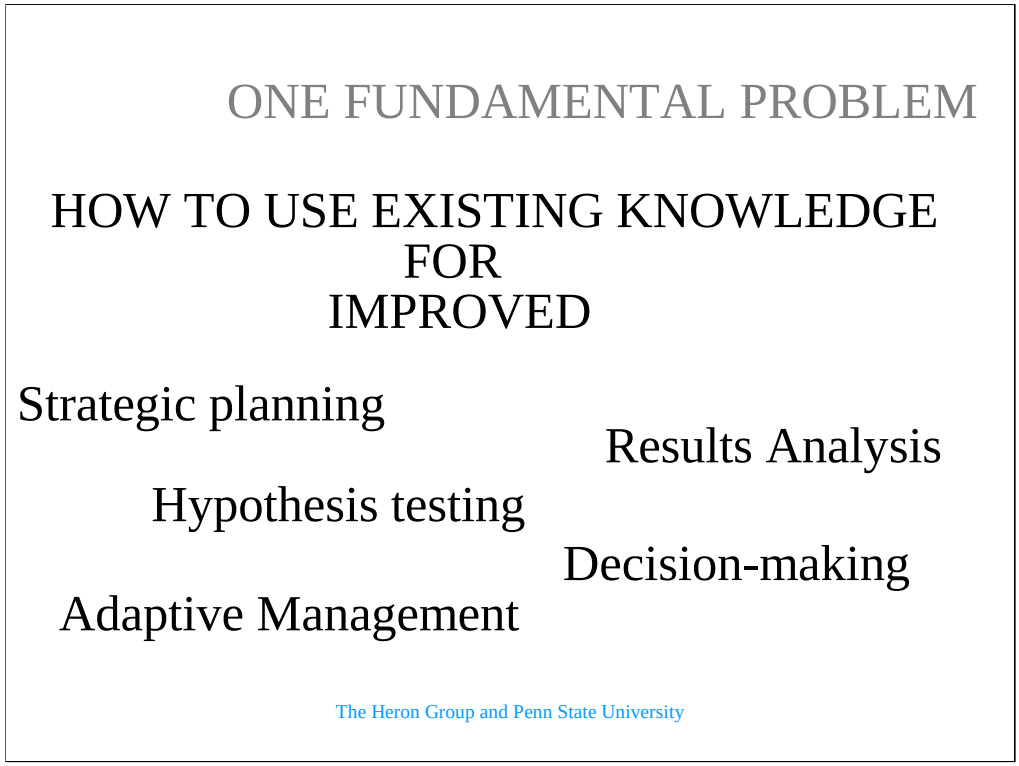
B. Different types of information including:

1. Simulation model output, such as that which might portray development hypotheses, assumptions, and understanding of how we think the world works.

2. Heuristics of human experts--i.e., the rules by which professional and indigenous experts understand and respond to a given situation or problem.

3. Tabular databases--which might include information tracking specified indicators over time, and

4. Spatially referenced data, such as we find in Geographic Information Systems, maps, etc.



Because knowledge is cumulative over time it doesn't take long before we are so inundated with information that we are literally confused by the facts. What is needed is some coherent means of using this information in the many different ways that shown in this slide.

ONE SOLUTION

USE ENABLING TECHNOLOGY

SUCH AS

ARTIFICIAL INTELLIGENCE

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There are different ways that information can be structured, but we want to focus on just one, Artificial Intelligence or AI as it is often referred to.

ARTIFICIAL INTELLIGENCE SYSTEMS

Can be used to apply knowledge-based reasoning logically and
to develop mathematically robust solutions

to evaluate more imprecise information

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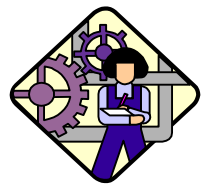
Artificial Intelligence systems are knowledge-based, which implies the use of heuristics or rules of thumb. We prefer not use the latter term because of its negative, gender related derivation. But, the point is that artificial intelligence systems, can be used to develop mathematically robust solutions to complex problems and can be used to evaluate less than precise information.

TRADITIONAL APPROACH TO CONSTRUCTION OF ARTIFICIAL INTELLIGENCE SYSTEMS

Involves close interaction between:

(a) Knowledge Engineer



(b) Subject Matter Expert

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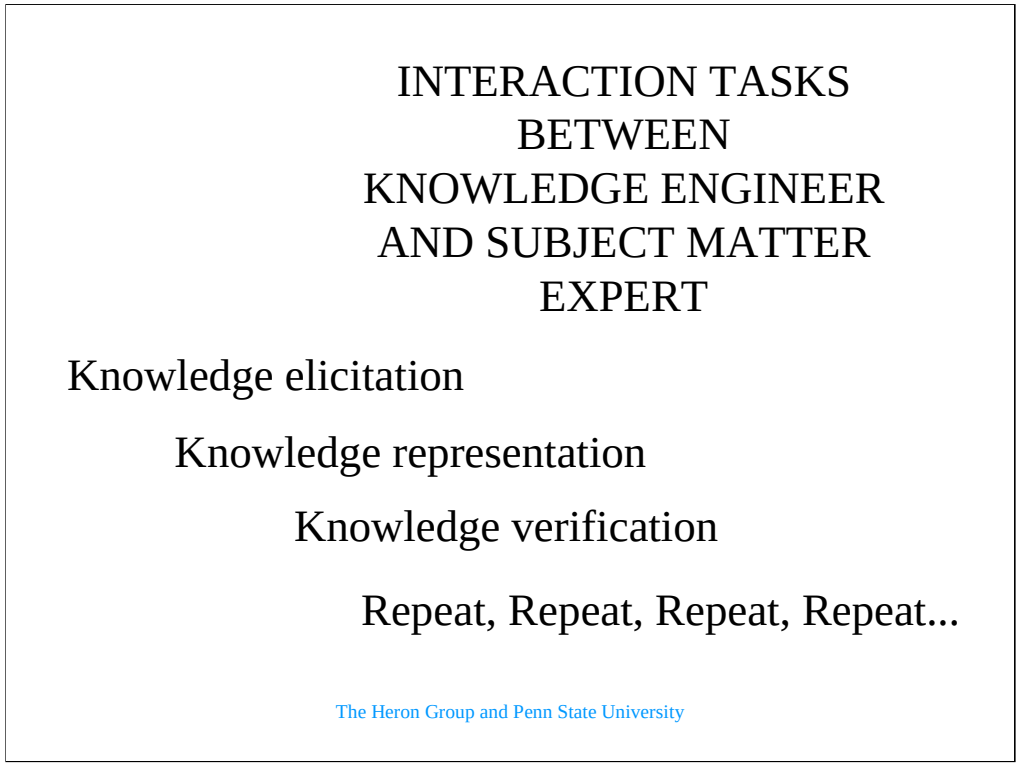
The traditional approach to the construction of a knowledge base for Artificial Intelligence software traditionally involves:

1. A Knowledge Engineer who elicits, organizes, and programs information obtained in a process of facilitating knowledge transfer, and

2. A Subject Matter Expert or Domain Expert who is recognized as being knowledgeable or experienced in the area of concern to the Knowledge Engineer



The interactions between the Knowledge Engineer and the Subject Matter Expert involve the following:

1. Knowledge Elicitation--This involves the transfer of domain specific knowledge from the Subject Matter Expert to the Knowledge Engineer.

2. Knowledge Representation--This involves the coding of the elicited knowledge by the Knowledge Engineer into machine readable form.

3. Knowledge Verification--This involves the testing and validation of how well the coded knowledge represents what the Subject Matter Expert/Domain Expert knows.

4. Repeat, Repeat, Repeat, Repeat....--This involves an iterative verification process until the Subject Matter Expert is satisfied with the coded knowledge representation.

RESULT OF INTERACTIONS

This Artificial Intelligence System is

Often Referred to as a Knowledge-Based System

The Knowledge Base is a set of rules for processing data and information for the system(s) for which it was developed.

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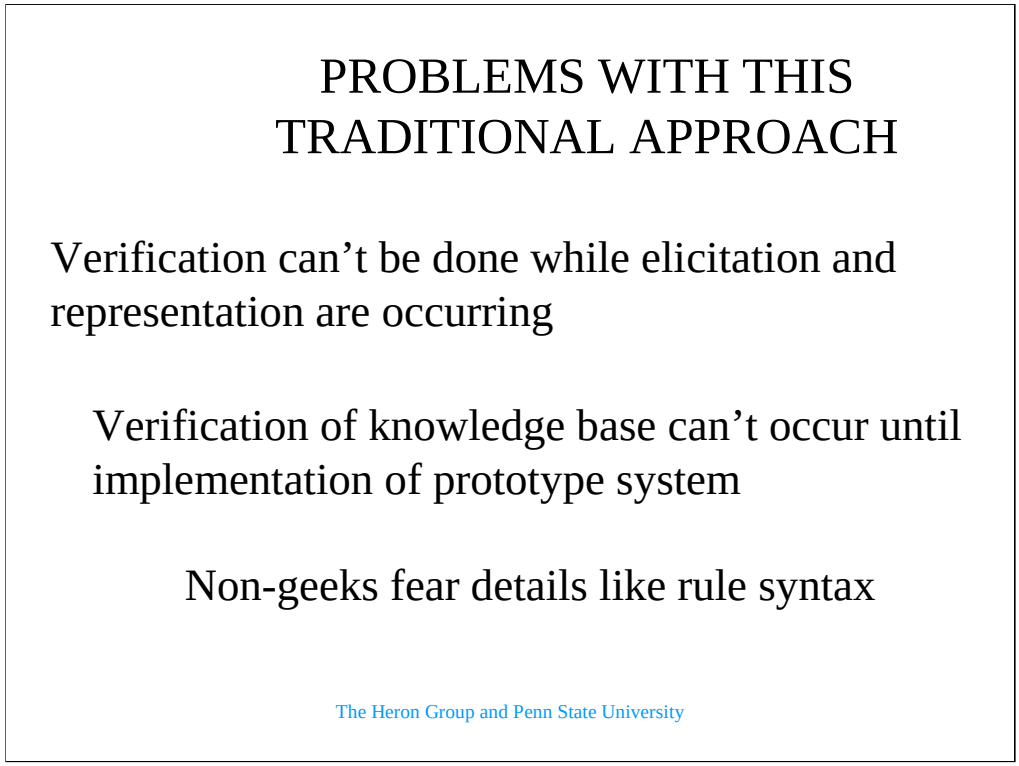
As stated earlier, AI systems are often referred to as being knowledge-based because of the underlying heuristics that make them so different from traditional data bases.

As indicated earlier, the knowledge base is a set of rules or heuristics that can be used to process data and information for the system for which it was developed.



Up to this point, we have been discussing the development of traditional AI systems and as we shall see these systems do have some problems and limitations.

The first of these is that verification cannot take place until all information about the system has been elicited and represented mathematically. The simple reason for this is that the knowledge base must be completed before it can be tested.

Likewise, the knowledge base can't be verified until the complete prototype of the AI system has been completed so that all interactions can be coded and tested.

Coding does require rule syntax and this can be a real turnoff for many people who might otherwise be interested in learning about and using AI.

PROBLEMS, CONT.

Inherently requires yes/no, black/white, true/false, etc. answers to data questions.

Rules must be written for every condition or set of conditions being analyzed.

Traditional AI systems also require discrete data for rule development. The implication here is that this kind of knowledge base does not allow "shades of gray" or levels of imprecision.

Consequently, rules must be written for every condition. This is a very laborious process and if a rule is missed or or left out, the knowledge base won't work, or if you don't know what a rule is, it can lead to incorrect conclusions.

What to do? What to do?

NetWeaver

But, of course!

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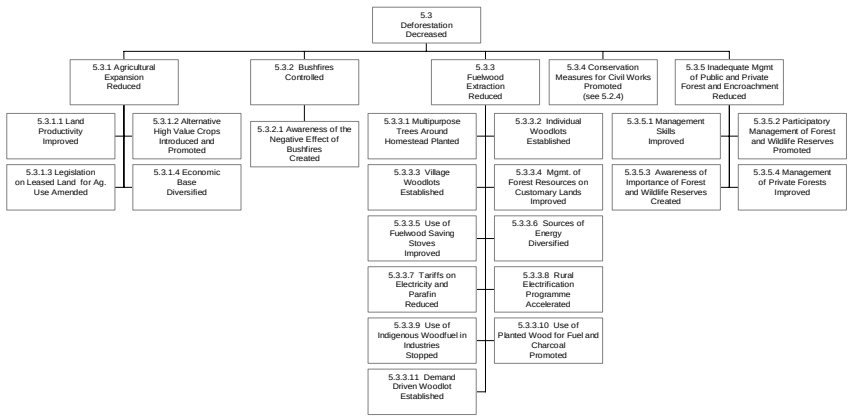
NetWeaver is an AI shell that was developed by Dr. Michael C. Saunders and Bruce Miller at The Pennsylvania State University. It was originally developed for use on complex natural resource issues and is now being used by the U.S. Department of the Interior (USDI) Fish and Wildlife Service, the Environmental Protection Agency (EPA),and the U.S. Department of Agriculture (USDA) Forest Service. The Heron Group, LLC, with Dr. Saunders, is working with USAID to see if NetWeaver can be used to resolve complex issues in sustainable development.

STRATEGIC PLANNING GRAPHIC

5.3 ACTIONS TO ADDRESS DEFORESTATION



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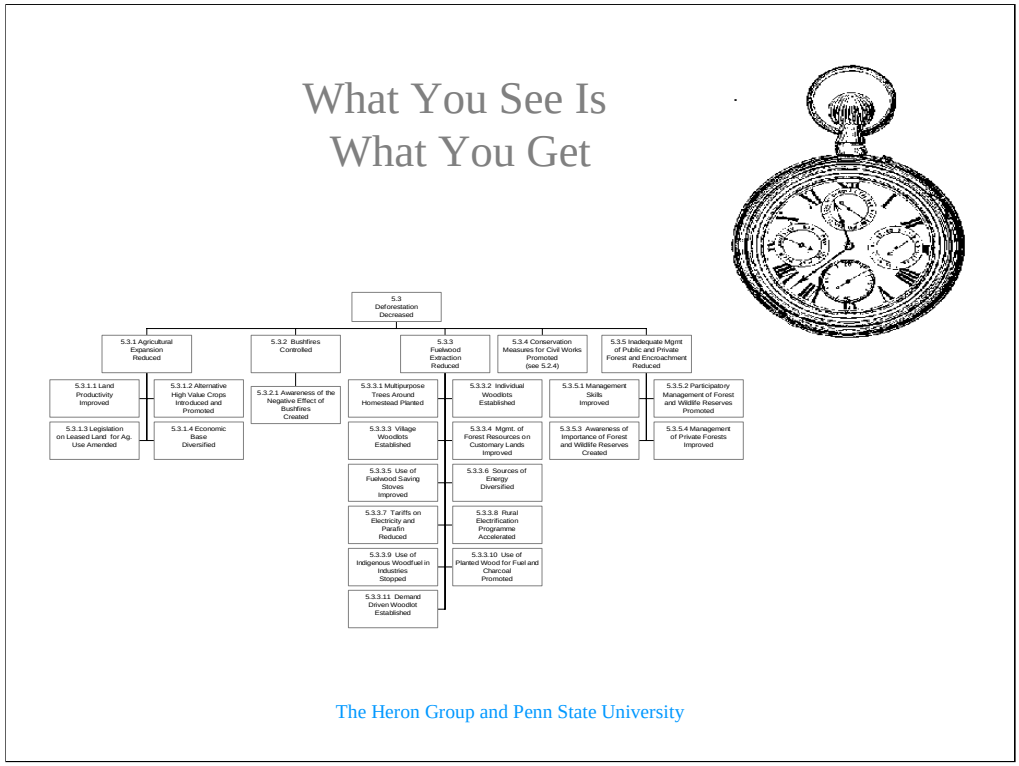
This is one part of a National Environmental Action Plan (NEAP) that we selected to demonstrate some NetWeaver features. This particular chart displays a strategic approach to address the key environmental issue of deforestation.

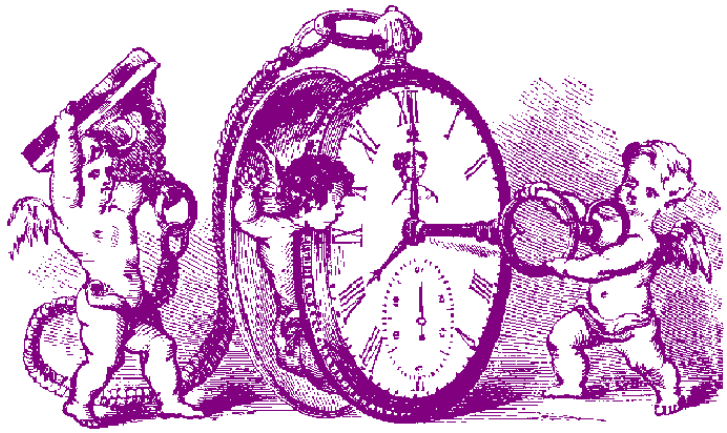
There was no such chart in the original planning document but using the Results Framework process, we were able to set it up as you see here. Note that there are five groups or branches of Intermediate Results (IRs). The different branches represent different causality groups and within them, different levels of causality.



This is the same chart as in the previous slide. We've used NetWeaver to model the dependency networks but it's obvious that WYSIWYG--What You See Is What You Get. What we mean by this is that the chart is like the face of a watch. It is quite straightforward, easily read, and easily understood.

What the framework doesn't show are the actual dependency networks that are the foundation of the framework because like any watch, it isn't necessary to understand how the watch works in order to tell time. As we proceed through the next series of slides we'll be following the dependency network within the first branch. This branch focuses on the linkages between the reduction of agricultural expansion and a decrease in deforestation.

WHAT YOU DON'T SEE IS ALSO WHAT YOU GET



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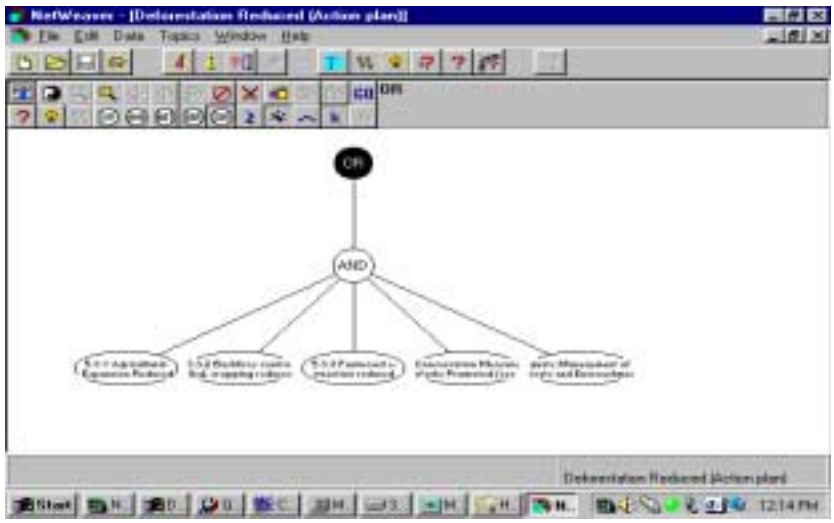
As we suggested in the previous slide, NetWeaver operates like a watch. Although the dependency networks are not visible to the user unless specifically called up,they are always there for the user's bidding.

And, as we see here, the cherubic Knowledge Engineers are opening this watch so we can see the works inside, and understand better how NetWeaver works.

Dependency Networks



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Here we see an actual "screen capture" from NetWeaver. It is an example of a modular component of the framework we saw earlier. In this case, we are looking at the first level of the dependency network and it shows each of the intermediate results in one of the five ovals. The ovals, by the way, are a signal that there is another level of dependency that can be observed by double clicking on the oval that represents the particular dependency link you are interested in following.

In this example, we will follow IR 5.3.1 (Agricultural Expansion Reduced) located in the first oval. It's worth noting that the lines between ovals and the "and" circle represent heuristics associated with a domain problem and are, in addition, a useful shorthand for representing those heuristics and the data and conclusions that depict the underlying logical relationships. The "or and "and" circles will be covered shortly.

IR 5.3.2 is: Bushfires Controlled

IR 5.3.3 is: Fuelwood Extraction Reduced

IR 5.3.4 is: Conservation Measures for Civil Works Promoted

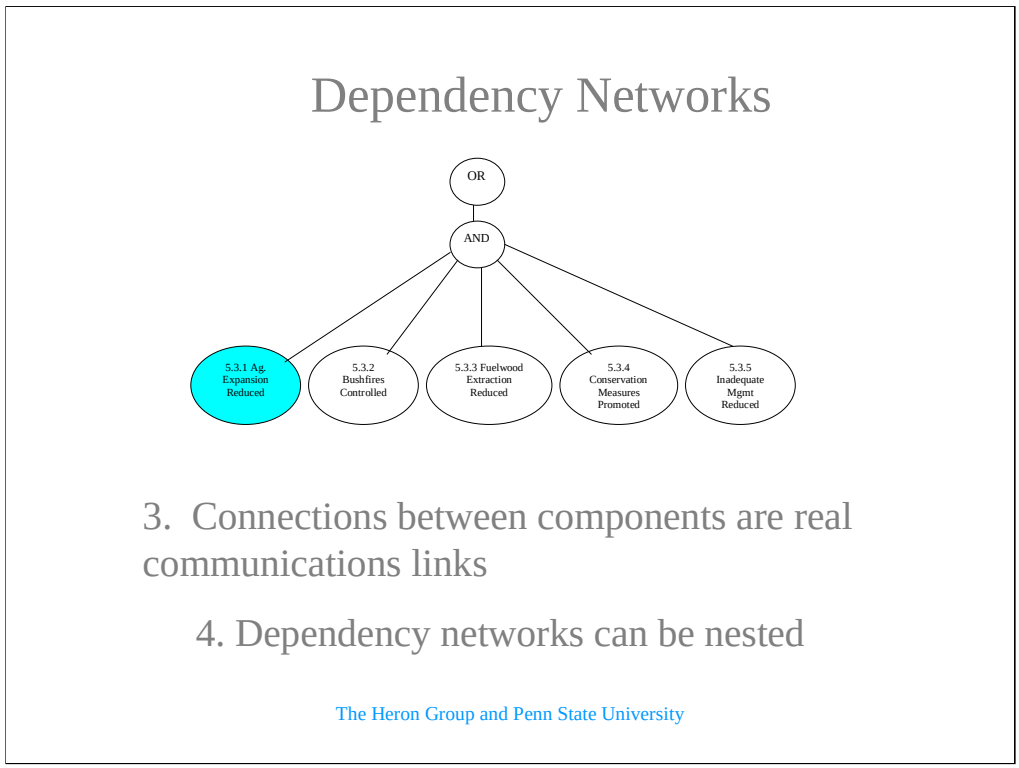
IR 5.3.5 is: Inadequate Management of Public and Private Forest Encroachment Reduced

Dependency Networks

1. Used to graphically depict logical relationships between data and conclusions, providing a very useful shorthand for representing heuristics associated with a problem domain.

2. Built from simple logical components

Importantly, NetWeaver can graphically (as shown here) or textually portray logical relationships identified by Subject Matter Specialists.



Top Circle: OR is an AI convention for representing the possibility of more than one solution.

Middle Circle: AND is an operator that indicates that truth depends on this linkage. For instance, in this example, Deforestation Reduction is dependent on all 5 conditions in the ovals below the AND being "true".

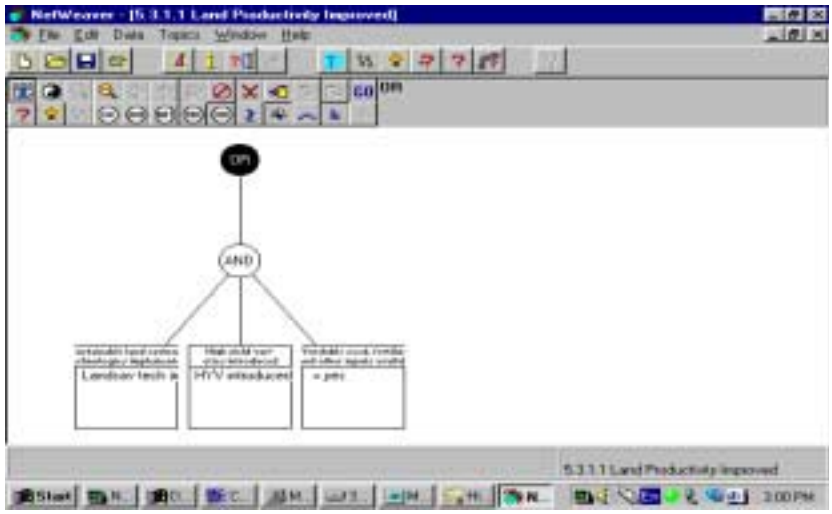
The five oval shapes across the bottom of the graphic represent dependency networks for IR 5.3.1 through 5.3.5, i.e., the dependencies thought necessary and sufficient to achieve a reduction in Deforestation.

Let's look at the dependencies under

5.3.1 Agricultural Expansion Reduced (illustrated in the shaded oval).

NOTE: The oval indicates another level of dependencies exists or that data boxes may be accessed (as in this case) by double clicking on the appropriate oval.

FUZZY LOGIC



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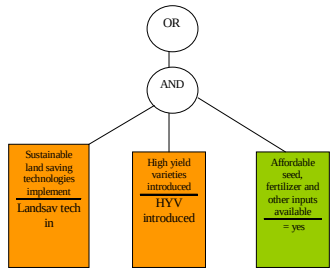
This particular dependency network has led us to a level where we actually have data boxes represented instead of the ovals we saw previously.

The first box will use a numerical value in regard to how many land saving techniques were introduced; the second will contain information on how many high yield varieties were introduced; and the third is asking if affordable seed, fertilizer, and other inputs are available. Note that the third box is dissimilar to the first two in that it only requires a yes/no response.

FUZZY LOGIC

Bivalent Logic: Every statement or sentence is true or false. (A or Not A)



Multivalent Logic: Everything is a matter of degree including truth and set membership. (A and Not A)

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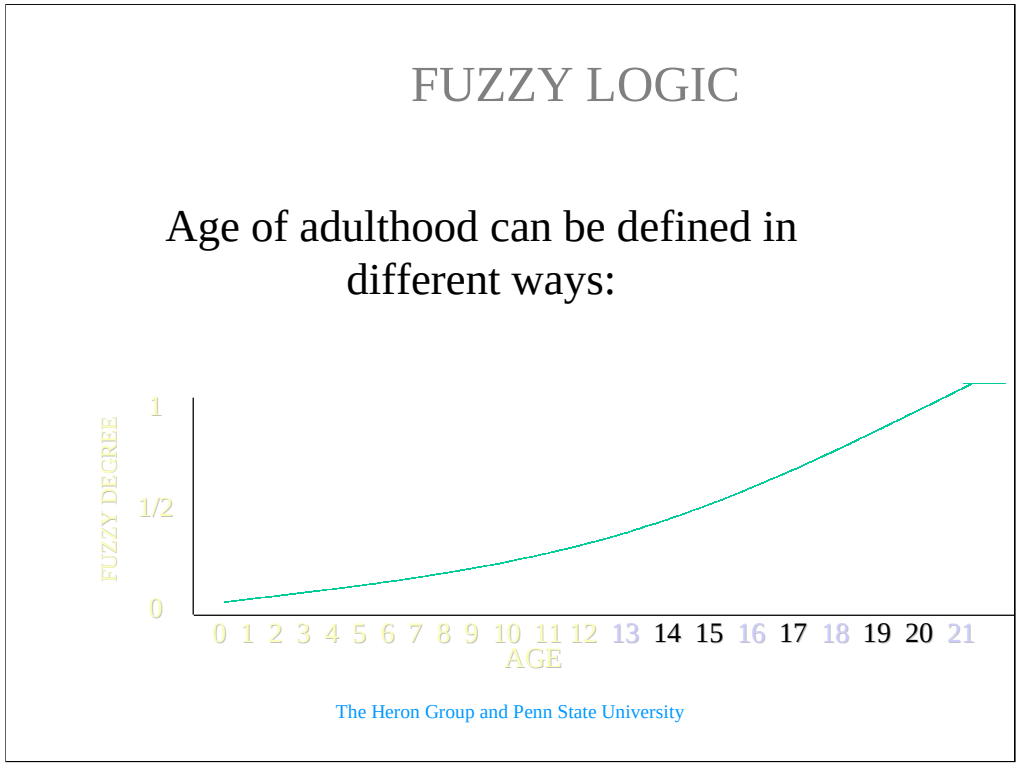
Continuing from the previous slide, the third box is an example of bivalent logic where the response is always one of a two set condition such as true/false, yes/no, etc..

Contrast this with the first two boxes which indicate a non-bivalent response or the use of multivalent logic. This means that, in the case of the first box, there will be a numeric response required that NetWeaver will match against a fuzzy set to determine the degree of membership or trueness. The fuzzy set parameters were developed earlier by the Knowledge Engineer and the Subject Matter Specialist.



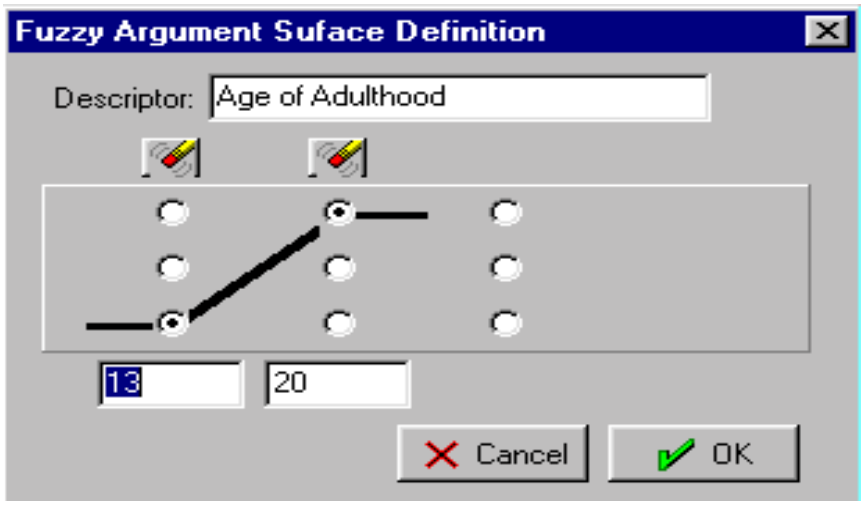
To better explain fuzzy logic and fuzzy set theory, let's consider age of adulthood in males in the U.S. The age curve in the graph shows a progression from childhood towards adulthood which is achieved at age 21.

We've highlighted the ages of 13, 16, and 18 to indicate that there are other cultural and legal determinants of adulthood. For instance, we know that some religions or cultures consider a boy to become an adult at age 13 when they complete some cultural ritual such as a Bar Mitzvah.

We also know that a concession to adulthood is made in the U.S. at age 16 when most states grant some form of driving privilege and again at 18 when a male is old enough to join the military. And, of course, we consider that when a person reaches 21, they are an adult and are legally responsible for their actions including the consumption of alcoholic beverages.

So, having indicated the various ages, if we select any single age along this curve we are forced into a bivalent logic mode which would not be true for any of the ages under 21. Instead, we want to be inclusive and represent all of these conditions and we can do this by creating a fuzzy logic set which ranges from 13 to 20.

FUZZY LOGIC



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This is the NetWeaver screen that sets up the fuzzy logic set for the Age of Adulthood scenario we saw in the previous slide. Note that a simple entry of the beginning age of thirteen and the last age in the fuzzy set of 20 describes the values that will comprise the fuzzy set. Any datum that is entered and belongs to this fuzzy set will have met some condition for membership in the set, and the degree of truthfulness will be calculated.

It is this fuzzy logic capability that separates NetWeaver from other AI programs and provides it with analytical advantages that can be used to quantify relationships that heretofore have been somewhat daunting to consider, including social and cultural parameters which may be more qualitative or less crisp than precise quantitative measures.

UNIQUE ADVANTAGES OF NETWEAVER AS A KNOWLEDGE BASED SYSTEM

Graphical display of knowledge base states

Modular knowledge base design

Get consensus for each module

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Having access to a graphical display of knowledge base states means the user can gain an understanding of the knowledge base simply by "seeing" the inner workings. This includes but is not limited to seeing the dependency network relationships, Boolean operators, and fuzzy logic arguments.

Having a modular knowledge base design means that the complexity of the total system can be broken down into smaller units or modules that are much easier to understand, represent, and verify.

Getting consensus for each module means that a large knowledge base can be quickly built by aggregating already verified smaller modules and, as mentioned above, the verification process is much quicker for smaller modules.

ADVANTAGES OF NETWEAVER

Fuzzy set memberships of data and conclusions give greater sensitivity for decision making and avoid “spurious specificity”

Real time evaluation of knowledge base greatly expedites knowledge engineering tasks.

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One of the real problems associated with bivalent responses is that one incorrect response can shut down an entire dependency module.

e.g., if one of the major descriptors of old growth forests is trees being 180 years old, do you reject old growth if the trees are only 179? This, by the way, is what is meant by "spurious specificity".

ADVANTAGES OF NETWEAVER

Knowledge base verification can be completed before implementation in prototype system.

Comparing data values to fuzzy arguments eliminates the need to address all combinations of data values.

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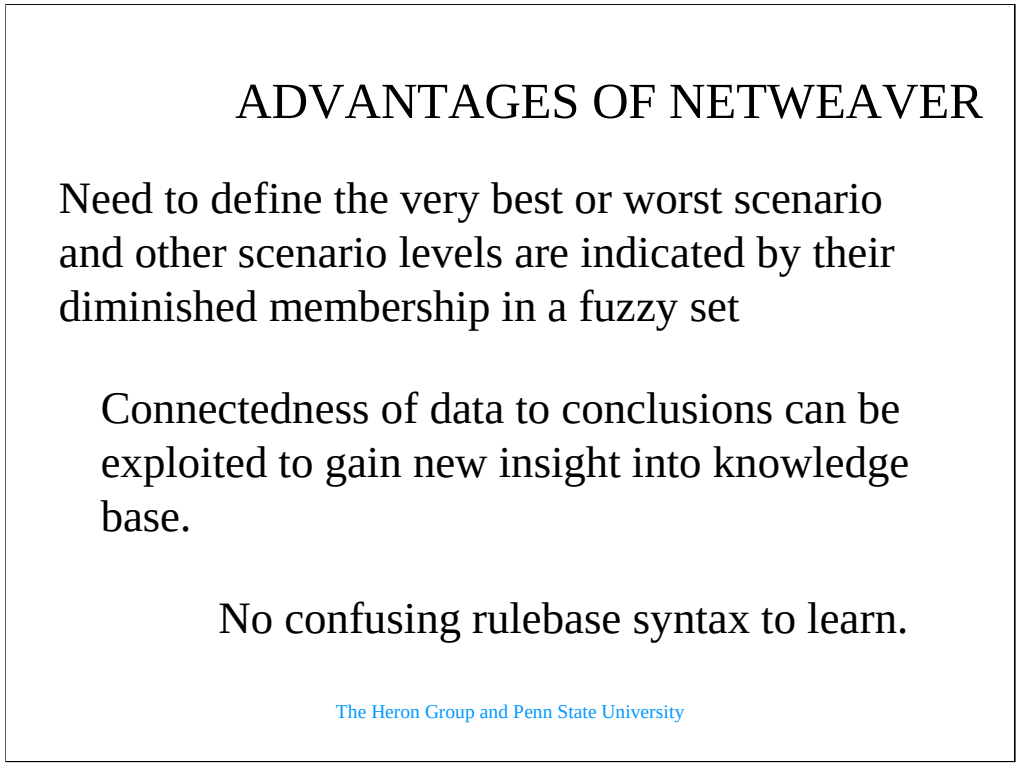
This was discussed earlier, but another strength of NetWeaver is it's ability to model components or parts of dependency networks. This feature greatly simplifies verification of that module by itself and therefore it is not necessary to wait until the entire knowledge base is developed before verification can begin.

Perhaps of even greater significance is NetWeaver's capability to compare data values to fuzzy sets which then eliminates the necessity of writing rules to address all combinations of data values.



One of the greatest advantages of NetWeaver, as we have already seen, is that it no longer is necessary to capture every kind of possible interaction in the knowledge base. Rather, it is only necessary to define the very best or the very worst scenario since all other scenario levels are indicated by their level of membership in the fuzzy set. This condition all but elininates bivalent logic and with it, spurious specificity.

Another advantage of NetWeaver is that the modular construction of dependency networks leads to a greater degree of connectedness of the data to conclusions and this can be exploited to gain new insight into the knowledge base.

For instance, one can follow decisions from the highest level of dependency through the network to the lowest level where actual data are being evaluated.

Still another advantage of NetWeaver is that it eliminates the confusing rulebase syntax so common to traditional AI software.

WHAT NETWEAVER CAN DO TO HELP ACHIEVE SUSTAINABLE DEVELOPMENT

Facilitate discussions to identify meaningful SOs, IRs, Activities, and Indicators in RFs

Facilitate creation of dependency networks to test development hypotheses in an iterative process

Accept data (including GIS), link data sets, and show data impacts on expected results

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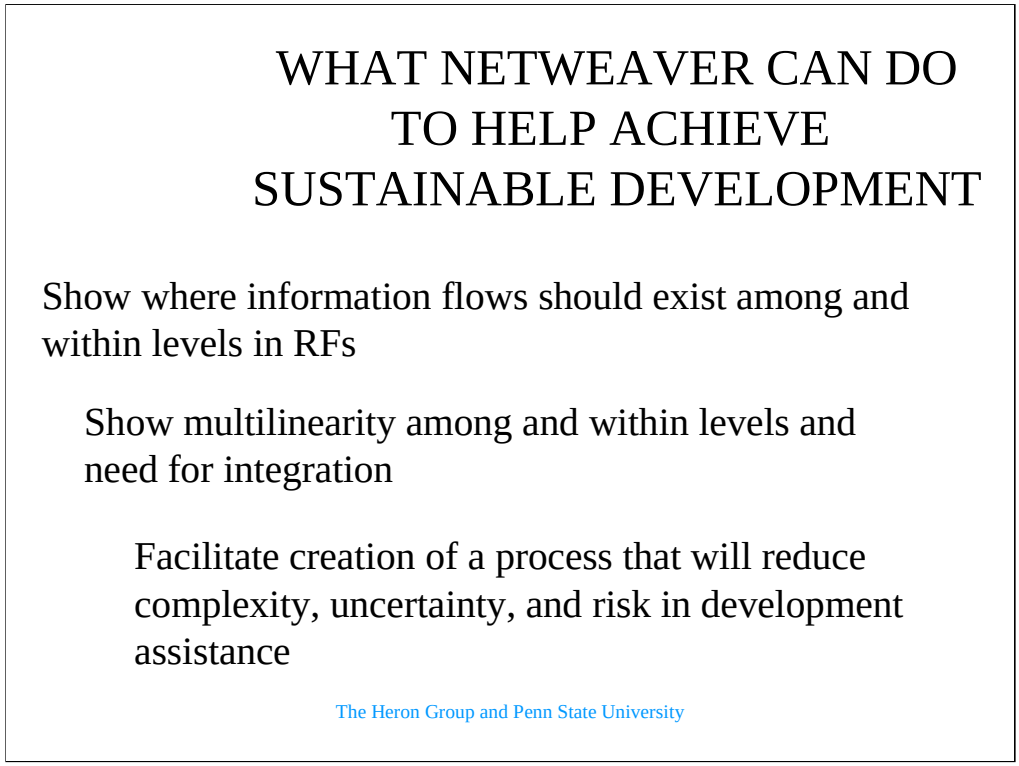
NetWeaver is a great facilitation tool in the RF process because it enables each member of the Strategic Objective (SO) team to see and evaluate how the SO, IRs, Activities and Indicators hold up under close scrutiny with simulated data.

More importantly, when set up as independent modules it is possible not only to see relationships in the dependency networks but it's also possible to test these dependencies by using simulated data to test hypotheses and make instantaneous adjustments should they be necessary.

Once the relationships and dependencies are agreed upon and are set up by NetWeaver as networks, it is then possible to challenge them with real data, if available. NetWeaver has no limitations on kinds of data that can be used including spatially referenced data.



NetWeaver's dependency networks not only use data effectively, they also show precisely where the information flows exist within the modular networks and also between and among them. In this manner, NetWeaver graphically shows how information flows between different IRs and even between different SOs.

NetWeaver can demonstrate the non-linear aspects of complex systems. Feedback loops exist. As progress is made toward achievement of one result, it may have a positive or negative impact on another result. Multilinear relationships in a complex world can be documented, characterized, tested, and validated.

NetWeaver, for the reasons stated above, greatly facilitates a process that reduces complexity and uncertainty in creating and using RFs and accordingly, can contribute significantly to risk reduction in development assistance.

WHAT NETWEAVER CAN DO TO HELP ACHIEVE SUSTAINABLE DEVELOPMENT

Facilitate appropriate monitoring and evaluation in RFs

Provide updates on activity and status at all management levels

Facilitate management and decision-making at all levels in RFs by being responsive to changing conditions

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NetWeaver can facilitate appropriate monitoring and evaluation through the modular dependency networks because the lines between data boxes and ovals represent logical relationships between data and conclusions.

Consequently, any monitoring data will almost immediately signal whether or not a given indicator is appropriate for evaluation. If the data are appropriate they can be evaluated and used to indicate how well a given activity is progressing.

NetWeaver can also facilitate management and decision-making at different levels for the same reason as given above. If monitoring and evaluation are proceeding and generating information that activities are or are not proceeding as anticipated then, indeed, management can make decisions that will be based on what is actually occurring.

WHAT NETWEAVER CAN DO TO HELP ACHIEVE SUSTAINABLE DEVELOPMENT

Facilitate appropriate accountability at all levels

Reduce agency costs through efficient use of resources available and by supporting performance based budgeting and performance targeting

Facilitate accurate and up-to-date report generation.

The Heron Group and Penn State University

NetWeaver facilitates accountability because it provides information to the manager about activity status and because it does so, it provides a clear course of action--sustain the work if it's doing what was expected or take appropriate action if it's not. Accountability lies in taking appropriate action at the appropriate time.

Accountability and good decision making help to reduce costs by reducing the amount of resources being expended on non-productive activities. Likewise, as we have seen how NetWeaver can be used to develop dependency networks, it is also possible then to support performance based budgeting and performance targeting. That is, a decision maker, can take positive steps to reallocate resources to accelerate activities that are performing up to expectations.

Finally, NetWeaver, because of the capabilities described above can obviously facilitate good reporting. In fact, we are taking steps to include a report generator as a new fuction for NetWeaver. With reports being generated automatically, truly, the concept of WYSIWYG will be accomplished and non-technical users will be able to avoid opening the watch but will still feel confident to use NetWeaver and be willing to base decision making on NetWeaver reports.